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SHRP2 Naturalistic Data Analysis of Older Drivers' Gap-Acceptance Behavior

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ABSTRACT

Drivers aged 65 and older are very prone to motor vehicle crashes. Intersections appear to be hazardous for drivers of this age group due to the driver's cognitive, perceptual, and psychomotor challenges. Literature notes that older drivers find it incredibly challenging to navigate left turns at signalized intersections safely. Studies have identified the driver's physical health, vision, and cognition as factors that impact the ability of older drivers to sufficiently monitor the gaps in oncoming traffic to make a left turn safely. The current paper aims to address the gap in the literature by explicitly examining older drivers' gap acceptance behaviors during left turns at protected intersections. We utilize the Naturalistic Driving Study Data collected via the Strategic Highway Research Plan (SHRP2) to understand older driver behavior better. SHRP2 makes available a geo-spatially linked, comprehensive database over a multi-year period from over 3400 participants across six sites. SHRP2 databases contain a relatively more significant proportion of younger and older drivers than the national driver population databases. This dataset includes a trip summary, vehicle data, driver questionnaire, and test battery data specifying driving history, physical and psychological conditions, demographics and exit interview data, time-series data of the drivers approaching the intersections or just after the intersections, and forward video data of the drivers approaching the intersections or just after the intersections. Data is analyzed for participants over the age of 65 and participants between the ages of 30-50. Several hundred baselines, near-crash, and crash events are obtained for comparison. The video data is annotated using the DREAM methodology. The Roadway Information Database (RID) also considers additional variables such as crash histories and traffic and weather conditions. The samples of the forward video data provide the start time and end time of each gap accepted or rejected by the turning driver, especially when turning left, during unprotected phases, and help understand the participant's interactions with other vehicles just before and after the intersections. The data has been collected over multiple years across multiple sites, so the dataset is considered a multivariate time series model. As there is more than a one-time dependent variable, the data was analyzed using Extreme Gradient Boost (XGBoost), Long-Short Term Memory (LSTM), and Seasonal Auto-Regressive Integrated Moving Average with eXogenous factors (SARIMAX) models. These models are expected to achieve an accuracy of around 80 percent at four-way intersections and approximately 60 percent in T-intersections. We anticipate that the older drivers will exhibit longer gap acceptance times and a greater frequency of gap rejections than their younger counterparts while turning left across traffic at signalized intersections. The findings of the current study will have implications for older driver safety. Researchers may use the findings to understand gap acceptance behaviors further, while policymakers may utilize the results to design mobility guidelines.

Keywords: Gap acceptance, T-intersections, Long-short term memory, Seasonal auto-regressive integrated moving average with eXogenous factors

INTRODUCTION

Older drivers, aged 65 and older, are more likely to get into collisions when making left turns at intersections than younger drivers. This may be because older adults underestimate the speed of approaching vehicles and ignore other hazards. They report driving difficulty with, and avoidance of, specific driving scenarios. Furthermore, in cross-sectional studies, worse contrast sensitivity in older drivers is associated with a reported reduction in driving exposure and night driving cessation (Hutton, 2015). Some studies show that older drivers are more likely to cause crashes at intersections, make left turns at intersections, navigate lower speed zones (30 mph), and on rural roads with fewer lanes. However, few studies have examined the complexity of older drivers' routes to reach their everyday destinations. Older drivers make incorrect signaling errors, struggle with speed regulation, and are prone to rolling stops, compared to younger drivers (Simons, 2005).

Approximately 20% of traffic fatalities occur at intersections, and one-third of these fatalities occur at signalized intersections. Left-turn collisions account for about half of the fatalities at signalized intersections. Left-turn lanes are used to provide a safe location for left-turning vehicles to wait for a gap in traffic to turn left and are used to reduce rear-end collisions (Horswill, 2020). A driver's unsafe left turn behavior can include several driving behaviors that violate sound driving norms for left turns. These include lane drifting, right-of-way error, sudden/improper braking, slow movements, turning from the wrong lane, turning tight, turning wide, lane change with no warning, and driving on the wrong side of the road (Castellucci, 2020). Elderly drivers are most likely to sustain fatal injuries from motor vehicle accidents. Injuries to the head and neck, chest, pelvic area, and extremities are the most common. On highways, drivers who have a more significant gap between their vehicle and the oncoming vehicle are less likely to accelerate during the maneuver.

Gap acceptance behavior at uncontrolled intersections is affected by demographics, speed, volume, etc. Young drivers are likely to accept a shorter gap than middle-aged or older drivers (Swain, 2021). This maneuver is a complex and risky driving behavior that is important for traffic safety and operation. Older drivers struggle to adequately detect, perceive, and accurately judge the safety of a gap. Therefore, older drivers may experience more significant difficulties at non-signalized intersections because their vision is less accurate, and they are slower at responding to other vehicles.

Despite being the smallest population group, the elderly account for nearly 36% of all healthcare expenditures and are more often at fault in vehicular accidents. The elderly population face challenges beyond the physical harm and financial constraints suffered from vehicular accidents (Ikpeze, 2016). They also lose independence and autonomy when forced to give up driving, which leads to an overall decrease in quality of life and increased dependency on others.

DATASET

The first step of this research is to obtain the SHRP2 NDS data that we need for this analysis. The Virginia Tech Transportation Institute (VTTI) owns the full NDS dataset. In six states, the second Strategic Highway Research Program collected information from over 3,500 volunteer passenger vehicle drivers, ages 16 - 98. They collected data for 5.4 million trips, 2,705 near-crashes, 1,541 crashes, and over 1 million hours of video, which may be used to develop safety countermeasures. In the past, NDS and RID databases had not been linked. Therefore, studies using the RID had to search through the NDS to find their data. The NDS data are field data, and field data is messy. The NDS provides a data access guide, data dictionaries, and query system for accessing the complete data. A video viewer is available to view short segments of selected time series data and forward video for the crash and near-crash events. To access all the data, a researcher must first obtain an Institutional Review Board training certificate, agree to the terms of use, and sign a data-sharing agreement with the Transportation Research Board.

The naturalistic data collected through the SHRP2 study is helpful for traffic safety and older research. This data was collected during 2005–2010, a span of 5 years, from multiple locations in the United States of America (Zafian, 2021). The data consists of a clustered event-set of 200-300 crashes, near-crashes, and baseline events at signalized intersections.

This dataset provides information on driving behavior beyond what can be gained in a driving simulator or other controlled environment (Choudhary, 2019). This study involves collecting only aggregate data. The dataset contains Trip Summary, Vehicle and Driver questionnaire data that will include driving history, physical and psychological conditions, demographics, and exit interview data. Time series data of the drivers approaching the intersections or just after the intersections, Video data of the drivers approaching the intersections or just after the intersections are also present (Yan, 2005).

Drivers have to decide when it is safe to merge into another vehicle's lane and whether an approaching vehicle has to slow down to avoid a collision. Crash rates are predicted by the rate of traffic conflicts at a given intersection (Mazer, 2021). To study a driver's following distance and gap acceptance behavior, we need to measure it. The methods to measure following distance and gap acceptance behavior are challenging to use because of the contaminated environmental factors.

CONCLUSION

Based on the study results, new intersection designs should consider positively offsetting left-turn lanes, and retrofitting negative offset left-turn lanes to positive or zero offsets should be considered where feasible. The current gap-acceptance study assumes that the driver would accept only a minimum possible gap size, which is not always the same (Li, 2017). Many studies focused on the gap-acceptance decision itself; we can try evaluating the effects of traffic speed, driver age, and gender on gap acceptance behaviors in a driving simulator, as we have all this in our dataset. Many may not be generalizable to the general older driver population, as they focus on a healthy group of older drivers with few medical conditions. But many older drivers are prone to medical conditions such as vision impairment.

Drivers' gap acceptance choices are suboptimal, and their time-to-arrival estimates are affected by visual illusions and many other distractions. Further study of gap acceptance behavior may yield opportunities for reducing crash risk.

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